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# A STEP toward understanding wind power development policy barriers in advanced economies

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ABSTRACT

A widely accepted premise regarding wind power development policy is that implementation of economic policy instruments, which are designed to close the cost gap between wind power and entrenched fossil fuel power generation technologies, will significantly catalyze enhanced levels of wind power development activity. This paper contests this premise by arguing that non-economic barriers to wind power development have the capacity to significantly inhibit wind power development in industrialized nations despite the implementation of economic policy instruments. Forces which deter wind power development in four economically advanced economies that exhibit phlegmatic progress in wind power development – Australia, Canada, Japan and Taiwan – are identified and amalgamated into a STEP framework describing social, technical, economic and political forces that inhibit wind power development. The conclusions of this analysis are twofold. First, failure to mitigate these STEP forces may undermine the efficacy of any given economic policy instrument that aims to close the cost gap between wind power and entrenched generation technologies. Second, attempts to mitigate these impediments might represent a way to achieve better policy results with less government financial commitment.



**Contents**



## 1. Introduction

International negotiations aimed at reducing greenhouse gas emissions to mitigate advanced levels of global warming have been characterized by ideological chasms that are so wide they have begun to resemble a circular debate between schoolboys over which flavor of ice cream is truly the greatest in the galaxy. Yet, there is one area of common ground. Leaders of virtually every nation share a concern that replacing fossil fuel-based electricity technologies will adversely impact national economic well-being. As former UK Prime Minister Tony Blair summarizes, "*The blunt truth about the politics of climate change is that no country will want*

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*to sacrifice its economy in order to meet this challenge, but all economies know that the only sensible long-term way of developing is to do it on a sustainable basis.*"[1] Leaders from key nations such as the United States, China, India, Canada and Australia have all publically bemoaned that a transition away from fossil fuel generated energy will impair the competitiveness of domestic industries in international markets [1–3]. But is the phlegmatic pace of shifting to alternative energy technologies such as wind power really all about economics? Was Barrack Obama correct in his assessment of US energy policy that "*to truly transform our economy, protect our security, and save our planet from the ravages of climate change, we need to ultimately make clean, renewable energy the profitable kind of energy*"?[2] Or are there other obstacles which extend beyond the realm of economic rationality that inhibit the development of wind power, and if so what are they?

Comparing the costs of electricity generation technologies is a complicated, contentious exercise. The process of estimating current cost profiles critically depends on assumptions made regarding inputs such as the specific technological components to be used, future costs for fuel stock procurement, connection distance to the power grid, and capacity load factor estimates, to name but a few malleable factors. Emergent research suggests that, depending on assumptions made, wind power is not necessarily a more expensive technology in comparison to nuclear power, oil-fired power or gas-fired power [4–7]. Moreover, the majority of research indicates that if the external economic and environmental costs associated with the various forms of electricity generation were internalized, wind power would be an economically superior form of electricity generation even compared to coal-fired power [5,8,9]. In short, although there are no absolute claims that can be made when comparing generation costs across different technological platforms, there is evidence that cost disparity is not the only factor inhibiting wind power development.

This paper seeks to contribute to a clearer explication of barriers to wind power development by examining barriers that extend beyond traditional economic impediments. The article analyzes conditions influencing wind power development in four nations, which have a track record of under-performance in wind power capacity development – Australia, Canada, Japan and Taiwan – and then seeks to identify common impediments. Four industrialized nations were chosen in order to reduce selection bias [10]. These specific nations were chosen because in pairs they represent nations with contrasting wind power development challenges. On one hand, Australia and Canada are geographically large, federal nations with significant untapped wind power development potential. Both nations have an abundance of fossil fuel resources which provides these nations with a high degree of energy security. On the other hand, Japan and Taiwan are geographically constrained, densely populated nations that exhibit enormous energy demands. These nations are largely dependent on energy imports; and as such, they have a high incentive to embrace any initiatives which bolster domestic energy supplies. In all cases, these four nations have demonstrated a phlegmatic approach to wind power development policy despite the existence of some level of government developmental support.

To aid the identification and classification of barriers to wind power development in these nations, a STEP analysis was employed, wherein focused efforts were made to identify social (S), technological (T), economic (E) and political (P) factors that impinge on wind power development. In strategic management, a STEP analysis is a common tool for assessing exogenous influences on market development prospects [11]; and as such, it was deemed a transferrable tool for evaluating wind power market development prospects.

Data for the four case studies were acquired through the combination of literature reviews, government documents, energy industry statistics and unstructured interviews with stakeholders, where and when possible. Four detailed versions of the case studies have subsequently been published in international journals [12–15]. A three-step coding approach was adopted for collating the data. First, forces that were identified in two or more sources as impeding development of wind power were culled from the data collected. Second, these forces were assigned to one of the four STEP categories. For example, reports that some communities in Japan opposed wind power development due to a predilection for preserving community aesthetics were assigned to the "social" category of the STEP analysis under the heading "community concerns over aesthetic intrusion". Similarly, there were also reports that local maritime groups opposed offshore wind power development due to concerns over adverse impact on fishing grounds. This observation was also listed under the "social" category under the heading "community concerns over adverse ecological impact". Third, an attempt was made to reduce the total number of elements assigned to each STEP category by searching for commonalities of elements; and when identified, grouping the common elements into condensed categories. For example, the two social hurdles described above were combined under the condensed heading of "NIMBY concerns".

The outline of this paper is as follows. Section 2 employs the STEP framework to summarize all the main hurdles to wind power development uncovered in the four case studies. This represents step two of the coding process described earlier. Section 3 combines the insights from the four case studies and presents a STEP analysis at a higher level of abstraction that conflates commonalities found in the case studies. This represents step three of the coding process described earlier. Section 4 outlines areas for further research and presents concluding observations.

## 2. Case briefs

### 2.1. Australia

Given that Australia boasts 24.1% of the world's economically viable reserves of brown coal and 5.4% of the world's economically viable reserves of black coal, it should come as no surprise that coal-fired power dominates Australia's electricity mix. In 2006–07, brown and black coal accounted for 83.8% of Australia's electricity generation, with the remaining electricity supplied by natural gas (12%), hydropower (2%), oil (1%) and wind power (1%) [16].

Despite being a vast, scantily populated nation, wind power in Australia has fallen appreciably short of its technical potential. With most of Australia's coastal areas boasting average annual wind speeds in excess of 8 m/s [17], the potential of wind power to contribute at least 20% to Australia's electricity supply is almost unequivocal [18].

The new Labour government which recognises the need for a bolder commitment to renewable energy announced a National Renewable Energy Target (NRET) initiative, which upon commencement in 2010 will mandate purchases of renewable energy with the objective being to encourage a 20% contribution by renewable energy sources to Australia's electricity supply by 2020 [19]. Unfortunately it appears that the efficacy of the NRET will be undermined by program flaws such as inclusion of coal bed methane gas in the list of approved "alternative energy sources", a multiplier mechanism which encourages development of solar thermal energy systems at the expense of wind power, the limited duration of the program which will discourage investment after 2020 and failure to pass complementary legislation to enact a

[1] Tony Blair, *Speech to the London G8 Climate Change Conference*, 1 November 2005.

[2] Barack Obama, *Address to Joint Session of Congress*, 24 February 2009.

**Table 1**
Key STEP variables that impair wind power development in Australia.

| |
|---|
| *Social* |
| NIMBY concerns over aesthetics and ecological issues have stymied wind power development [22]. |
| Low electricity prices fuel social resistance to more expensive electricity generation portfolios [23]. |
| The fossil fuel industry is traditionally a major employer in Australia and still employs over 100,000 workers [24]. However, due to a 45% contraction of jobs since the mid-1980s [18], there is a high degree of sensitivity to the threat of further job losses in mining communities. |
| *Technical* |
| There are concerns over the stochastic properties of wind destabilizing grid load management [cf. 25]. |
| Liberalized electricity market complicates coordination of numerous, private electricity generators [26]. |
| Managing electricity inputs from many smaller wind power projects are more troublesome for utilities [27]. |
| Many regions of greatest wind potential are separated from the large population centers [17]. This increases the cost of transmission. |
| Australia's pooled purchase system for electricity complicates the process of integrating stochastic wind power inputs [26]. |
| *Economic* |
| External costs of fossil fuels are not internalized [8]. |
| Significant effort is currently expended on improving energy efficiency rather than financing alternative energy projects. This quick splash absorbs finances and planning time [28]. |
| Government support for carbon capture and sequestration means that fossil fuel power plants receive free R&D support [29]. |
| Government support of wind power technology innovation (i.e. improving storage etc) is scant [24,28]. |
| The NRET program is not ambitious enough to effectively catalyze improved economies of scale for wind power [24,28]. |
| Widespread concern exists over what higher energy costs will due to Australia's economy [29,30]. |
| Inexpensive and secure fossil fuel resource availability relieves energy security pressures [24,31]. |
| The inclusion of coal bed methane gas as an alternative fuel in the NRET creates an indirect subsidy to the coal industry [19,20]. |
| There is steadfast support for Australia's fossil fuel sector which contributes substantial export revenues and royalties to government coffers [23,32]. |
| *Political* |
| Fossil fuel electricity provision exhibits a degree of "stickiness" due to the existence of established supply networks and transmission and distribution infrastructure [32–34]. |
| As a key exporter of uranium and coal [24], there is considerable political pressure in Australia to support these industries [35]. |
| States control electricity supply management but strategic cooperation between states to work toward a carbon-free electricity system is low [36]. |
| Few concerns over foreign dependence on fossil fuel supplies because Australia is relatively self-sufficient [24]. |
| Government backtracking exists regarding original Kyoto Protocol commitments [37]. New short-term targets are too lax, long-term targets are too far off to catalyze immediate change. |
| Liberalized markets and decentralized generation make it hard to achieve technological collaboration [27,38]. |
| Commitment to other alternative energy technologies (notably solar thermal and geothermal) diffuses support for wind power [19]. |
| Rejection of $CO_2$ emission trading Bill undermines the efficacy of the NRET [28]. |

carbon emissions trading scheme [19–21]. A STEP analysis of the conditions which led to this state of affairs in Australia provides insight into why the NRET developed in this matter and highlights some of the hurdles that policy makers must seek to mitigate in order to enhance the scope and pace of wind power development (Table 1).

Table 1 summarizes the prominent barriers to enhanced development of wind power in Australia. Continued government subsidization of fossil fuel technologies and failure to internalize the external costs associated with each electricity generation technology have created a false economy wherein coal-fired power is perceived to be the best economic alternative for generating electricity. As a recent government report highlighted, if the hidden costs associated with fossil fuel combustion were internalized, the current cost differential between wind power and coal-fired power which currently stands at between 30 and $40 per megawatt hour [39], would be more than offset by a net increase of $42–$52 per MWh in the cost of coal-fired power [8]. Unfortunately, a proposed cap and trade scheme has failed to clear political hurdles; and as such, the internalization of costs associated with $CO_2$ emissions has yet to be achieved [21].

However, the cost disparity between coal-fired power and wind power does not fully explain languid wind power development in this nation of high wind power potential; nor does it fully explain why external costs have not been internalized. There are social barriers which include misperceptions that a transition away from fossil fuel technologies will adversely affect the economic well-being of communities dependent on fossil fuel mining revenues. There are also misperceptions that wind turbines will adversely impact the aesthetics and ecology of communities.

There are also technical barriers which center primarily on the stochastic nature of wind power. Concerns that high levels of wind power will destabilize the grid require technical solutions that require R&D support [33]. Similarly, the challenge of managing wind power inputs from numerous sources within the context of Australia's pooled electricity purchase system requires systematic restructuring of load management systems.

Finally, there is entrenched political support for Australia's fossil fuel industry and this support manifests itself through political initiatives to support carbon capture and sequestration research, the maintenance of robust fossil fuel support schemes and political resistance to the $CO_2$ cap and trade schemes mentioned earlier.

In summary, in addition to enacting initiatives to close the economic divide between the costs of coal-fired power and wind power, all of these non-economic barriers need to be mitigated if Australia's policy makers are to optimise wind power development policy.

### 2.2. Canada

Canada's electricity grid is the sixth largest in the world, supported by 124,240 MW of total installed generation capacity, incorporating six main generation technologies [40]. As Table 2 indicates, hydropower resources in Canada are in abundance. In 2008, only China produced more hydropower than Canada [41]. The responsiveness of hydropower generation makes it a perfect complement to wind power development [42]. Consequently, if Canada's provincial electricity grids were integrated and optimised, the predominance of hydropower within Canada's electricity mix and vast tracts of undeveloped land provide the necessary conditions to technically displace coal-fired power leaving Canada with an electricity mix dominated by low-carbon technologies (Table 2).

The main barrier to achieving the laudable goal of an electricity mix dominated by low-carbon technologies relates to the Canada's federal structure. Under Canada's federal charter, constitutional authority over electricity generation has been expressly assigned to Canada's provinces [43]. This constitutional fragmentation of electricity governance has spawned a national grid which is only

**Table 2**
2007 installed electrical generation capacity by source.

| | 2007 | % of total |
|---|---|---|
| Hydro | 73,435,687 | 59% |
| Wind and tidal | 1,600,399 | 1% |
| Coal | 27,211,548 | 22% |
| Nuclear | 13,345,000 | 11% |
| Internal combustion | 593,480 | 0% |
| Combustion turbine | 8,054,193 | 6% |
| Totals (capacity in kilowatts) | 124,242,314 | 100% |

Data source: statistics Canada, 2009.

loosely interconnected. Inter-provincial electricity connections are not nearly sufficient enough in order to allow electricity generated by hydropower sources to be effectively exchanged between provinces [44]. Moreover, some of Canada's provinces which happen to be rich in fossil fuel resources (notably Alberta and Saskatchewan) have insubstantial hydropower resources, accentuating fossil fuel dependence in these provinces [45]. As Table 3 illustrates, in considering approaches for resolving the fragmentation of Canada's electricity grid, the federal government faces a number of social, technical, economic and political hurdles.

Unquestionably, failure to internalize external costs associated with each electricity generation technology along with access to relatively cheap, abundant fossil fuel resources has created a false economy in Canada wherein fossil fuel-fired power is perceived to be economically superior. However, the economic cost disparities do not describe the whole story regarding languid wind power development in a nation with wind power potential that stands in the top echelon internationally. As Table 3 indicates, there are a number of significant social, technological, political and economic barriers which impede progress.

Constitutional delegation of authority over electricity governance to the provinces is patently the most significant of these barriers. It poses an enormous impediment to creating a national electricity management strategy that would provide the level of inter-provincial electricity grid integration and collaboration necessary to fully tap wind power potential.

Provincial authority over electricity governance also complicates resolution of many technological impediments. In order to ensure that stochastic wind power fluctuations do not destabilize provincial electricity grids, technical enhancement of sub-optimal inter-provincial grid connections is necessary; however, political incentive for enacting such technical fixes is currently weak. Provinces that are rich in hydropower, which serves a vital role in providing efficient peak load support capability, would be understandably reluctant to voluntarily impinge on provincial self-sufficiency in this inexpensive, low-carbon energy resource through sharing capacity. Meanwhile, provinces boasting fossil fuel resource abundance are able to exploit existing fossil fuel excavation and transportation infrastructure and enjoy an abundance of relatively cheap fossil fuel energy.

Even the economic realm is affected by Canada's constitutional structure. The current federal subsidy for encouraging wind power development of 1¢ per kWh has been criticized as insufficient for fostering significant change within the current electricity regime [47]. Without internalizing the external costs of fossil fuel combustion, closing the price gap between wind power and coal-fired energy would require a level of federal funding that is likely untenable as federal government attempts to reduce a vitiating federal budget deficit [49]. However, forcing provincial electricity regimes to internalize external costs is also less tenable when the provinces hold constitutional authority over electricity governance and each province views the challenge of abating $CO_2$ emissions from different perspectives and with differing perceptions of exigency [13].

Finally, although civic advocacy is prominent in Canada, there is a degree of insouciance in civic and environmental circles regarding $CO_2$ emissions from electricity generation. The primary concern in Canada is on improving energy efficiency related to transportation and inefficient end-use activities [53]. The electricity sector tends to fly under the environmental radar (except in fossil fuel-intense provinces) because 71% of Canada's electricity is generated by low-carbon energy sources (59% hydro, 11% nuclear, 1% wind) [40].

In summary, the Canadian case study mirrors the Australian study in indicating that economic fixes alone will not fully optimise wind power development. In Canada, political hurdles are arguably as influential in blocking wind power development as economic hurdles. Moreover, social and technical hurdles also need to be addressed if Canadian policy makers wish to better exploit Canada's wind power potential.

### 2.3. Japan

Japan faces daunting national energy security challenges. Japan's 127 million people (1.9% of the global population) consume

**Table 3**
Key STEP variables that impair wind power development in Canada.

| |
|---|
| *Social* |
| Heavy contribution from hydropower reduces social pressures to reduce carbon footprint associated with electricity [13]. |
| Historically low electricity prices [46] fuel social resistance to more expensive electricity portfolios. |
| *Technical* |
| Managing electricity inputs from many smaller wind power projects are more troublesome for utilities [13]. |
| Concerns exist over stochastic wind power flows destabilizing the grid because inter-provincial grid connections are sub-optimal [44]. |
| Weak grid inter-connectivity between provinces stymies capitalization of full wind potential [44] |
| Provinces that are rich in wind power potential (i.e. Alberta, Saskatchewan) seldom have access to hydropower for peak load support [45]. |
| Provinces that are rich in hydropower have low-carbon footprints and reduced incentive to invest in wind power [13]. |
| *Economic* |
| External costs of fossil fuels and nuclear power are not internalized [13]. |
| A federal production subsidy of 1¢ per kWh for wind power is insufficient to make wind power an economically competitive alternative to coal power [47]. |
| Abundant fossil fuel resources reduce energy security risk [46]. |
| There is strong support for fossil fuel in fossil fuel-rich provinces due in part to tax and royalty revenues earned on natural resource extraction [48]. |
| An acute federal budget deficit restricts the capacity to provide improved wind power production subsidies [49]. |
| *Political* |
| Fossil fuel electricity systems have a degree of "stickiness" due to the existence of established supply networks in many provinces [50]. |
| There is considerable political pressure in Canada to support oil, gas and coal industries due to their economic value [48,51]. |
| Provinces control electricity supply management but strategic cooperation between provinces to work toward a carbon-free electricity system is low [52]. |
| Few concerns over foreign dependence on fossil fuel supplies. Canada is largely self-sufficient [51]. |
| Government backtracking exists regarding original Kyoto Protocol commitments. The federal government has now announced less ambitious targets [53]. |
| Liberalized markets and no centralized control makes it hard to achieve national collaboration [44]. |
| Provincial constitutional authority over electricity governance enables provinces to resist federal attempts to coerce wind power development [13]. |

**Table 4**
Key STEP variables that impair wind power development in Japan.

| |
|---|
| *Social* |
| NIMBY opposition in a nation that values traditional vistas impairs site selection [57]. |
| Resistance to government plans (i.e. governance of electricity) is customarily muted [15]. |
| Geographic siting constraints exist due to high population density [15,58]. |
| *Technical* |
| Concerns exist that stochastic wind power flows will destabilize the grid. This nurtures demands to store wind power before feeding it into the electricity grid [59]. |
| Private regional utilities enjoy monopoly positions [55] which inhibits interconnected "smart" grid development. |
| Managing electricity inputs from many smaller wind power projects are more troublesome for utilities [15]. |
| Sites with the greatest wind potential are separated from main population centers [58,60]. This increases the cost of transmission [61]. |
| Entrenched prioritization of nuclear research (well over US$60 billion investment since 1981) [62]. |
| Low estimates for capacity load factor (20%) artificially inflate the cost of wind power [4,63]. |
| *Economic* |
| External costs of fossil fuel and nuclear power are not internalized [15]. |
| Advanced nuclear power is seen as the key technology for economically meeting Japan's future energy needs [64,65]. |
| Funding emphasizes energy efficiency initiatives over financing alternative energy projects [66]. This further diverts funding away from wind power storage. |
| Nuclear research is significantly subsidized by the government [62]. This results in artificially low cost estimates for nuclear power production [55]. |
| Research to improve storage of wind power received little government support [15]. |
| The renewable portfolio standard used to encourage development of renewable energy (targeting less than 1% of total electricity supply in 2009) is insufficient for substantively improving wind power economies of scale [59,67]. |
| Deep concerns exist regarding the impact of higher energy costs on a stagnant economy [68]. |
| *Political* |
| Nuclear power is a preferred long-term electricity technology due to its large-scale generation capability. Campaigns to improve the image of nuclear energy are evident [64,65]. |
| Nuclear power technology is considered to be an attractive export commodity [64,65]. |
| Fossil fuel electricity provision exhibits a degree of "stickiness" due to the existence of established supply networks [15] |
| Commitment to supporting other alternative energy technologies (notably solar PV) diffuses the market for wind power [62,69]. |
| Regional utilities are less motivated to reduce $CO_2$ emissions through alternative energy projects due to lack of direct government pressure. Meanwhile, wind power developers face interconnection hurdles established by the utilities [59]. |

5.3% of all power generated in the world [54]. Yet, over 97% of the energy consumed in Japan comes from imported fuel-stocks. Japan imports virtually all coal, oil and gas feedstock [55].

In order to improve national energy security, the government has announced a five-pronged strategy which includes the following goals: (i) improve energy efficiency by at least 30%, (ii) reduce oil dependence by 40% or lower, (iii) reduce oil dependence in the transport sector to 80%, (iv) target the share of nuclear power in electricity generation to 30–40%, and (v) increase the share of crude oil owned by Japanese companies to 40% [56]. In short, commitments to bolster renewable energy capacity are relegated to a secondary role in government energy security strategy. Wind power development in particular has been largely neglected. Table 4 helps to shed light on some of the hurdles that Japan's wind power developers face by summarizing the social, technological, economic and political factors inhibiting progress.

Of all the hurdles that wind power developers face in Japan, economic hurdles are the most daunting. Failure to internalize the external costs associated with fossil fuel and nuclear power creates sizable cost disparities between wind power and these entrenched power sources. Cost disparities are accentuated by ardent government R&D support for nuclear power and advanced fossil fuel power generation technology while R&D support for wind power and power storage technology is insignificant [62]. Most of Japan's utilities are so averse to managing the stochastic nature of wind power that wind power developers complain of being forced to store generated wind power prior to feeding it into the regional electricity grids [59]. This accentuates the cost disparity between wind power and the entrenched power sources. A renewable portfolio standard has been developed to encourage clean energy development but the mandated purchases for 2009 amount to less than 1% of the total electricity supply, too low to foster the levels of scale economies necessary to help wind power developers close the cost divide.

Although it may seem logical to conclude that policies aimed at rectifying the cost disparities between wind power and other entrenched power sources would pave the way for amplified levels of wind power development, political roadblocks complicate the challenge. In addition to political reluctance to enforce internalization of external electricity generation technology costs out of concerns that higher electricity prices might threaten industrial competitiveness, two other political barriers foster perpetuation of the status quo. First, the Japanese government has granted regional monopolies to 10 private vertically integrated utilities [55]. The higher cost of wind power undermines profitability unless utilities can successfully negotiate rate increases with inflexible government regulators. Therefore, utilities are reluctant to proactively pursue wind power expansion programs especially considering the technical burden of integrating stochastic power flows in the regional grids. Second, there is considerable political support for nuclear power capacity expansion [64,65]. Consequently, an enormous amount of government research funding goes to nuclear research (well over US$60 billion channelled to nuclear power research since 1981) [62] instead of to programs that could close the economic cost divide between wind power and the entrenched generation technologies. In short, the economic cost divide is a symptom of much more complex political obstructions.

Of the social factors that tend to deter wind power development, the civic apathy toward a national energy policy which supports nuclear power development over the enhancement of renewable energy capacity is most striking given the anti-nuclear sentiments that still exist in Japan. There appears to be an underlying belief that despite the hazards posed by nuclear power, particularly concerning waste disposal, technological solutions will eventually be developed to mitigate the externalities caused by nuclear power [15].

In summary, the Japanese case highlights the ineluctable nature of many of the STEP elements. Barriers in one realm (i.e. economic) are frequently underpinned or supported by obstacles in other realms (i.e. political, technological and social). Therefore, policy initiatives to alter electricity governance should seek to mitigate all STEP obstacles in order to minimize systematic impediments to policy effectiveness.

### 2.4. Taiwan

Despite having a small population, Taiwan was the 17th largest national consumer of electricity in the world 2008, with aggregate

**Table 5**
Key STEP variables that impair wind power development in Taiwan.

| |
|---|
| *Social* |
| Social and political divisions over nuclear power keeps nuclear power on the agenda [72,77,78]. |
| There are geographic siting constraints due to high population density [79]. |
| There are NIMBY concerns regarding offshore wind development driven by perceptions of adverse impact on fisheries and protected marine species [12,80]. |
| *Technical* |
| Concerns exist regarding stochastic wind power flows destabilizing the grid. This results in demands by Taipower for wind power developers to build sub-transformers at each wind site [12]. |
| Managing electricity inputs from many smaller wind power projects are more troublesome for utilities [12,81]. |
| Sites with the greatest wind potential (east coast) are separated from major population centers (west coast) [79,82]. This increases the cost of transmission. |
| Differences of opinion over total wind power potential in Taiwan results in political reluctance to aggressively pursue wind power [12,83]. |
| *Economic* |
| External costs of fossil fuels and nuclear power are not internalized [12,79]. |
| Deep concerns exist regarding the impact of higher energy costs on an already flagging economy [73,77] |
| Funding emphasizes energy efficiency initiatives over financing alternative energy projects [84]. |
| Government support for wind power research to improve storage is insufficient [12,84–86]. |
| The procurement price used to encourage development of wind power is criticized as insufficient for fostering development beyond the most attractive sites [12,76,87]. |
| Financial budget constraints at Taipower limit prospects of the utility spearheading wind investment [88]. Development is left largely to market players. |
| 25-year electricity purchase contracts fix the generation profile for long periods of time [12]. |
| *Political* |
| Taiwan is not a party to the UNFCCC framework so there are no formal international commitments to reduce $CO_2$ emissions [89]. |
| The public utility has no competition and so decisions made on the electricity mix are final [12,73]. |
| Fossil fuel electricity provision exhibits a degree of "stickiness" due to the existence of established supply networks [12]. |

electricity consumption of 233,000 GW hours [70]. Like Japan, Taiwan is heavily dependent on imported fuel-stocks for power generation. Imported fuel-stocks fuelled 81.1% of all electricity generated in 2006 (coal—39.3%, oil—8.3%, LNG—14.3%, nuclear—19.2%) [71], with the remainder coming from hydropower and co-generation. Although imports of coal rose significantly in the 20-year period 1986–2006, growth in oil imports slowed due to government efforts to replace oil-fired power with LNG-fired power. In terms of low-carbon power sources, national hydropower capacity has nearly reached peak potential, nuclear power capacity is expected to increase by 2.7 GW in 2011 when Taiwan's fourth nuclear power plant commences operation [72] and renewables (solar and wind power) have been slow to develop as utility-scale power sources [71]. Historically, responsibility for the generation, transmission and distribution of electricity in Taiwan has rested with Taipower, which is a public monopoly. Virtually all transmission and distribution lines in Taiwan are still installed and owned by Taipower [73], but the electricity generation sector is undergoing privatization [73,74].

In the short-term, Taipower plans to further encourage wind power capacity development, aiming for an ultimate goal of 2159 MW of installed wind power capacity by 2010 [75]. In 2009, a Renewable Energy Development Bill was passed after 7 years of political debate and resistance. However, the development of concrete subsidies will be delayed because a newly formed Energy Commission must now deliberate over setting appropriate pricing levels. In the meantime, Taipower has an interim program in place for purchasing wind energy at US 6.16¢ per kWh. Despite criticism that US 6.16¢ per kWh is insufficient to stimulate large-scale investment [76], wind power capacity in Taiwan continues to progress albeit sluggishly. As of 2008, there were 155 wind turbines amounting to 281.6 MW of installed capacity at various locations around Taiwan. As Chi-Yuan Liang, an economist at Academia Sinica summarized, achievement of the 2159 MW target is doubtful given such a low current base.[3]

Estimates of wind power potential in Taiwan are both disparate and contentious. Taipower, for example, estimates that total *technical* potential for wind energy in Taiwan amounts to 4600 MW of onshore potential and 9000 MW of offshore potential. However, current land-use restrictions and competition for development results in a much lower estimate for *realizable* wind energy potential—1000 MW onshore and 1200 MW offshore. On the other hand, Infravest (Taiwan's only private wind power developer) estimates that 3000 MW of onshore wind power and 5000 MW of offshore wind power could be feasibly realized if Taipower increased its wind power procurement rate from the current level of US6.06¢ per kWh to US12.12¢ per kWh. Table 5 summarizes the major STEP barriers to wind power development in Taiwan.

In Taiwan, as in the other three case study nations, failure to internalize external costs associated with fossil fuel sources of electricity artificially inflates the economic attractiveness of fossil fuel electricity generation. However, cost disparity does not tell the whole picture. For example, oil-fired power cost Taipower an average of US15.33¢ per kWh in 2008, considerably less than the US12.12¢ per kWh which would purportedly catalyze significant offshore and onshore wind power development [12]. Yet, Taipower has been reluctant to alter its current interim procurement price for wind power of US6.06¢ per kWh for many of the non-economic reasons explicated in Table 5.

Taipower's resistance to integrating high levels of wind power stems from a number of technical and operational concerns. First, Taipower contends that realizable wind power potential in Taiwan is limited and; therefore, wind power does not represent a viable long-term solution to low-carbon electricity generation. Second, Taipower engineers are concerned that incorporating significant levels of wind power will complicate load management due to the stochastic nature of wind power. Third, Taipower has significant sunken capital investment in fossil fuel power plants and has commitments to long-term fuel stock supply purchase contracts which lock Taipower into current technologies [12]. Finally, Taipower is going through financial difficulties due to reluctance of the national government to permit Taipower to charge higher electricity prices to cover rising fossil fuel costs [88]. Accordingly, it does not have the financial resources to risk investing in a power source of dubious potential.

These technical, political and economic influences on strategic behavior at Taipower are exacerbated by delays in passing and implementing the Renewable Energy Development Bill which would provide a legislative justification for Taipower to raise electricity prices to finance wind power development initiatives. Taiwan's civic society has also played a minor yet not inconsequential role in the political process. Special interest groups concerned about adverse impacts to Taiwan's fishing industry and endangered marine species (such as the white-beaked dolphin)

[3] Source: Bloomberg New Service, "Energy Bureau Looking to Boost Wind-Power 10-fold", 28 September 2007.

**Table 6**
A STEP framework of factors influencing wind power development.

| Social | Technical | Economic | Political |
|---|---|---|---|
| NIMBY concerns | Stochastic nature of wind power | Externalities not internalized | Political conflict over optimal electricity mix |
| Level of civic activism | Multi-stakeholder grid management | Other competing alternative technologies | Level of fossil fuel industry opposition |
| Geographic hurdles | Logistical "Bother" | Subsidies to traditional technologies | Diffused alternative energy support |
| Market information asymmetry | Distance to grid | Insufficient renewable energy subsidies | Energy efficiency initiatives prioritized |
| Social complacency | Inadequate R&D to improve storage | Long-term fossil fuel purchase commitments | Complacency regarding $CO_2$ reductions |
| Electricity price sensitivities | Underestimated potential | Market players lack investment incentives | Vertically integrated utility monopoly |
| Concerns over community impact | | Government budget limitations | Weak adjoining grid coordination |
| | | National advantage in other energy resources | Lack of R&D support for wind power |

have provided politicians who are opposed to wind power development with the necessary backing to stymie implementation of the Renewable Energy Development Bill.

In summary, wind power development in Taiwan, like in the other three case study nations, is not impeded by just one or two barriers. A number of obstacles from all four STEP realms conflate within Taiwan's electricity regime to create a network of mutually reinforcing, ineluctable barriers that all need to be addressed in order to optimise wind power development policy.

## 3. Toward a generic STEP framework of factors hindering wind power development

In reviewing the STEP elements inhibiting wind power development in the four case study nations summarized in Tables 1, 3–5, common elements became evident. Consequently, a coding exercise was undertaken in order to cluster the variables identified in each case study into fewer but broader categories in order to enhance manageability [90]. The result is a framework composed of seven social forces, six technical forces, eight economic forces and eight political forces which describe the generic forces that stymie wind power development in the four nations (Table 6). In this section, each of the forces will be briefly summarized from a policy context.

### 3.1. Social factors

1. *NIMBY Concerns* include perceptions that wind power developments adversely affect living standards and/or the surrounding ecology. It is noteworthy that international experience with wind power indicates many NIMBY concerns are misplaced. For example, in contrast with concerns in Taiwan that offshore wind power plants could adversely affect the marine habitat, research in Europe indicates that the concrete foundations of offshore wind turbines can actually provide a safe harbour for the cultivation of corals necessary to support many aquatic creatures [91]. Similarly, concerns in Japan that onshore wind power turbines will degrade the beauty of scenic vistas have been contradicted by international experience wherein public support for wind power is generally positive in communities where such developments have been established [92,93]. The lesson for policy makers is that public perceptions need to be managed in order to minimize NIMBY resistance and separate actual threats from misperceptions [22].
2. A low *Level of Civic Activism* was exhibited in Japan where citizens tend to avoid interfering in the process of governance. Politicians are elected to do a job and the decisions they make (i.e. insufficient nuclear waste disposal planning) are not scrutinized to the extent they are in other countries. Nations characterized by low civic activism tend to exhibit political regimes driven by special interests (i.e. fossil fuel interests) and susceptible to groupthink [15].
3. *Geographic Hurdles* are typically evident in smaller, densely populated nations such as Taiwan and Japan. In such nations, the erection of wind turbines will inevitably intrude on communal space; thereby, posing wind power developmental hurdles and inflaming NIMBY opposition.
4. *Market Information Asymmetry* refers to insufficient public knowledge regarding the external costs associated with fossil fuel and nuclear power generation. If the public were more aware of the total costs of fossil fuel power generation, wind power developments would stand a better chance of being supported both in communities and at the national level because the economic disadvantage frequently attributed to wind power would be eliminated. For policymakers, it is imperative to ensure the public fully understands the true total costs associated with all generation technologies.
5. *Social Complacency* is a form of environmental "Dutch Disease" that is characteristic of countries which enjoy an abundance of renewable resources, such as hydropower in Canada or geothermal power in Iceland. In terms of proactive public support, here appears to be diminishing returns as levels of installed renewable power capacity increase.
6. *Electricity Price Sensitivities* were understandably evident in all case study nations. Concerns that adding higher percentages of comparatively expensive wind power to the electricity grid would adversely affect national economic well-being represent a common source of opposition to enhanced levels of wind power. However, academic evidence does not support these perceptions. A study done by the Australia Institute concluded that adding approximately 5% more wind power would only cost consumers AU$15–$25 per year extra [39]. The lesson for policymakers is that fear-mongering that seems to be linked to campaigns to oppose wind power needs to be countered with scientific enquiry to ascertain actual impact.
7. *Concerns over Community Impact* were evident in fossil fuel rich nations. In countries such as Australia and Canada, the fossil fuel sector is a major employer in some communities. Such communities are particularly sensitive to the threat of job losses associated with declining domestic use of fossil fuel resources. Given insatiable overseas demand for fossil fuel resources such concerns are often misplaced. Nevertheless, for policymakers, the bifurcate challenge is (i) to rectify any misperceptions through studies estimating actual impacts and (ii) to clearly communicate the economic benefits that wind power projects generate which in many countries have demonstrated a proclivity to produce positive net employment [94,95].

### 3.2. Technical factors

1. The *Stochastic Nature of Wind Power* is frequently mentioned by utility managers and policymakers as a key deterrent to more aggressive wind power development policies. This concern was

evident in all four case study countries but frequently exaggerated. The stochastic nature of wind power only becomes a threat to grid stability at high levels of wind power contribution. Not only has international experience demonstrated that up to 20% wind power can be incorporated into an electricity grid by utilizing existing spare capacity to provide stability, a number of mitigating techniques have also been developed to attenuate output fluctuations [25,42,96]. Furthermore, even after all technical attenuation techniques have been exhausted, research has shown that existing storage technology adds only $10–$20 per MWh to the cost of wind power [6,18,39]. In short, policymakers should be aware that although there is some validity to technical concerns over the stochastic nature of wind power, these concerns are frequently exaggerated either due to lack of sufficient technical knowledge or due to political gamesmanship.

2. *Multi-stakeholder Grid Management* hinders wind power development in Japan, Canada and Australia. In Japan, 10 regional utilities enjoy monopolies over their respective regional grids. In Australia and Canada, the electricity grids in each state (or province) are administered by separate organizations, some public and some private. Effectively interconnected grids enhance system stability and support higher levels of wind power [42,97].
3. *Logistical "Bother"* tends to be an issue ignored by mainstream academic research but is an evident hurdle when speaking informally with engineers from electricity utilities. In order to integrate high levels of stochastic wind power flows into a power grid, load management systems have to be revised, wholesale electricity purchase programs need to be altered to suit unpredictable wind power flows and a greater number of grid connections must be installed and maintained. All of these obligations represent logistical activities that would otherwise not require attention. Consequently, for many engineers, wind power represents a logistical "bother".
4. *Distance to the Grid* can render wind power projects commercially unviable. It has been estimated that the infrastructure costs associated with connecting to a grid in advanced economies are at least US$80 per meter [61]. Therefore, if one were to establish wind turbines in a remote area in order to avoid NIMBY opposition, the connection cost for every 10 km span would amount to US$800,000. The obvious lesson for policymakers is that in order to minimize the cost (per kWh) of wind power in remote regions, larger scale wind power projects should prevail.
5. *Inadequate R&D to Improve Storage* is both a technical and a political issue. The capability to economically store power would eliminate hurdles associated with the stochastic nature of wind power. Realizing the full promise of wind power and solar PV power depends on the development of economical storage technologies.
6. *Underestimated Potential* was evident both in Japan and Taiwan. In Japan, wind power potential was estimated using a capacity load factor of 20% which was extremely conservative when compared to international data which suggests that 30–35% is more representative of current technological capacity. Substituting a capacity load factor of 30% instead of 20% would yield a wind power potential estimate that is 50% higher. In Taiwan, the national utility (Taipower) and Taiwan's largest wind power developer (Infravest) have released wind power estimates that differ by over 360% [12]. If the Taipower estimate is accurate, wind power potential in Taiwan is relatively low and other technologies should be prioritized. If the Infravest estimate is accurate, more emphasis should be given to supporting wind power development. In summary, although estimates of wind power potential are technical in nature, estimates are based on assumptions which underpin them, which in turn are influenced by ideologies and politics.

### 3.3. Economic factors

1. *Externalities Not Internalized* refers to the economic costs associated with the social and environmental impacts of electricity generation technologies. External costs of any type are rarely incorporated into electricity generation cost data. For fossil fuels, $CO_2$ emissions represent the most significant economic externality. For nuclear power, storage of nuclear waste and decommissioning of obsolete plants represent significant externalities. Failure to include these real external costs into the true total cost of electricity generation for each power source distorts market forces. For example, one Australian study indicates that if the environmental cost of greenhouse gas emissions were internalized, the cost of brown coal-fired power would increase by US$34/MWh, the cost of oil-fired power would increase by US$26/MWh and the cost of gas-fired power would increase by US$17/MWh [8]. Given the average wholesale price of electricity in Australia is $A40/MWh [8], internalizing economic costs associated with just greenhouse gas emissions would significantly alter electricity market dynamics. The distortions caused by failure to internalize externalities unquestionably represent the largest barrier to wind power development within the STEP framework.
2. A dominant presence of *Other Competing Alternative Technologies* hinders the development of wind power in two ways. Firstly, when governments prioritize other alternative energy technologies, they tend to commit higher levels of R&D and market support to these technologies. The end result is a self-fulfilling prophecy wherein the technologies that receive more support begin to display commercial progress thereby justifying further support. Perhaps the best example of this is in Japan's nuclear power industry. Thanks to government investment of over $60 billion in R&D support since 1982, Japan's nuclear power industry boasts generation costs that are competitive with most other forms of fossil fuel energy provision [62]. However, it is conceivable that $60 billion invested in virtually any alternative energy technology would achieve similar progress. Secondly, in many nations, financial support for renewable energy technology R&D and capacity development is limited. Consequently, gains by other technologies are made at the expense of wind power development. This is exemplified in Australia wherein power contributions from small-scale solar thermal technologies are favoured. In the first year of the program, every 1 kWh of solar thermal power reduces the potential market for all renewable energy by 5 kWh due to a multiplier mechanism [19].
3. *Subsidies to Traditional Technologies* still exist in many nations despite global warming concerns. All four of the case study nations subsidize traditional technologies in some manner. In Australia and Canada, government financial support exists for carbon capture and storage research [28]. In Japan, nuclear power research receives enormous government financial support [62]. In Taiwan, the government subsidizes research in advanced fossil fuel generation technology [72]. Not only do such subsidies mask the actual costs associated with traditional technologies, the financial commitments detract from the pool of government funding that could be used for supporting wind power development.
4. *Insufficient Renewable Energy Subsidies* are particularly problematic in the absence of policies to internalize external costs associated with fossil fuel combustion. In all four case study nations, renewable energy subsidies failed to close the cost divide between fossil fuel electricity generation and wind power. Despite the nature of the policy tool employed – Japan has adopted a renewable portfolio standard, Taiwan has adopted a fixed procurement rate, Australia has adopted a mandatory purchase program, and Canada has adopted a production tax

credit – in all cases, the aggregate subsidy was insufficient to allow wind power to effectively compete with fossil fuel technologies. The bottom line is that subsidies which fail to close the economic gap between the cost of fossil fuel electricity generation and wind power will produce sub-optimal results.

5. *Locked-in Fossil Fuel Purchase Commitments* represent an economic hurdle to wind power development because long-term purchase obligations tend to delay phasing out undesirable technologies such as coal-fired power. Conditions in both Japan and Taiwan exemplify the "stickiness" that long-term fossil fuel purchase obligations have on the pace of technological transition. Both nations secure fossil fuel supplies through long-term purchase contracts with overseas suppliers; and once these commitments are made [12,15], the technologies that utilize these supplies often become entrenched for the duration of the purchase contract.
6. *Market Players Lack Investment Incentives* is common in nations where government support for wind power is unclear (Taiwan, Australia) or nugatory (Canada). In many affluent nations, wind power purchase guarantees are frequently of insufficient value and duration to provide wind power developers with the confidence necessary to begin making long-term market development commitments. Research indicates that wind power purchase guarantees need to be at least 15 years in duration in order to allow wind power developers to fully amortize project costs [61]. Failure to provide such guarantees leads to exploitative behavior in which wind power developers seek to develop economically attractive sites and then turn to other markets for new projects. Such is the case in Taiwan.
7. Insufficient support for renewables due to *Government Budget Limitations* emerged as a notable barrier to wind power development in Canada where an enormous federal budget deficit severely curtails the government's ability to bolster renewable energy development subsidies [13]. However, the existence of a national budget deficit is not the only obstacle in regard to government financial support. Periods of economic contraction tend to impair government revenues and place pressure on policymakers to find ways to support established levels of government service provision with reduced budgets. Accordingly, in stagnant economies, acquiring sufficient government financing to close the cost disparities between fossil fuel powered electricity and wind power is a contentious budget allocation issue. Overall, policymakers in support of wind power development need to understand that a number of interests compete annually for a fixed pool of government funds and financial support for wind power is usually achieved by demonstrating that financially supporting wind power is a superior use of fiscal funds. This is a political process that requires systematic planning in order to maximize funding success.
8. *National Advantage in Other Energy Resources* of some type poses barriers to wind power development in Australia, Canada and Japan. In Australia and Canada, governments enjoy sizable revenue flows from fossil fuel royalties and taxes [16,48]. Accordingly, in both nations there is a high degree of political will to support fossil fuel industries and this translates into initiatives such as government funding for carbon capture and sequestration, despite indications that other alternative energy technologies may represent more prudent long-term electricity generation solutions. In Japan, advanced waste processing technology and nuclear reactor design are seen as promising exportable commodities which deliver the dual benefit of providing concentrated flows of comparatively cheap electricity and export revenues [64,65]. The lesson appears to be that governments have a hard time disaggregating domestic energy planning from strategies to support fossil fuel or nuclear technology exports. Energy sources that have high export value tend to engender support within domestic electricity regimes.

### 3.4. Political factors

1. *Political Conflict over the Optimal Electricity Mix* can be conceptualised on three levels. First there is understandable conflict between actors who support the status quo and those who seek some level of change. Resistance to those seeking change can be significant, as illustrated by rejection of legislation in support of $CO_2$ emission trading in Australia. Second, within the realm of those seeking change, there are frequently competing interests. These competing interests frequently oppose each other in the same manner that parties seeking change oppose parties who wish to maintain status quo. For example, in Australia, geothermal energy, concentrated solar thermal energy and wind energy are all supported by vocal groups of supporters, each seeking to obtain an increased portion of a fixed market. Furthermore, some alternative technologies are better equipped to financially compete against wind technology. For example, in Japan and to a lesser extent in Taiwan, there are strong pro-nuclear groups that argue vociferously for government research funding, thereby drawing funds away from wind power support initiatives. Finally, the existence of abundant supplies of fossil fuel or uranium gives rise to a political form of "Dutch disease". One common reason why wind power potential in both Australia and Canada is underutilized is that both nations boast an abundance of traditional fuel stock reserves. Such wealth tends to discourage the level of strategic stretch necessary to proactively embrace a transition to renewable technologies.
2. *Fossil Fuel Industry Opposition* inhibited wind power development in all four case study nations. Entrenched fossil fuel regimes enjoy considerable cost economies thanks to historical subsidization of fossil fuel generation infrastructure, decades of cumulative R&D investment (frequently supported by government subsidies) [98] and political lobbying to discourage policies to internalize the external costs of fossil fuel combustion. In addition to commercial advantages, a fossil fuel plant can be operational for more than 30 years [5]. These plants represent capitalized investments which locks-in utilization of fossil fuel generation plants.
3. *Diffused Alternative Energy Technology Support* is a political obstacle as well as an economic obstacle because diffused research funding commitments detract from funding for R&D relevant to wind power. In Japan, financial support for solar PV research detracts from funding that could be channelled into storage technology research. Similarly, in Australia, government support for solar thermal, geothermal and carbon capture and sequestration technologies channel funding away wind power development initiatives. Furthermore, in countries which have mandatory renewable energy purchase programs, such as Australia, diffused support for alternative energy technologies typically reduces the market potential for wind power because it allows more technologies to compete for pieces of a fixed market.
4. The *Prioritization of Energy Efficiency Initiatives* is a political barrier in that the decision to prioritize energy efficiency (i.e. Japan and Taiwan) represents a political decision to exploit short-term gains before investing in sustainable energy technologies. Commitments to energy efficiency programs reduce the pool of funding available for other clean energy initiatives; and as such, hinder financial support for wind power R&D and market development. Although the situation is most

evident in Japan, virtually all nations with $CO_2$ abatement strategies have embraced the notion that energy efficiency initiatives represent necessary first steps.

5. *Complacency Regarding $CO_2$ Reduction* programs is a political artefact that is enhanced by (i) the absence of concrete international political commitments (i.e. Taiwan is not a signatory to the Kyoto Protocol), (ii) political confidence that other policy measures will achieve the requisite $CO_2$ reductions necessary to meet international obligations (i.e. Japanese authorities are confident that energy efficiency improvements can significantly abate $CO_2$ emissions; Australian authorities view carbon capture and sequestration as the low-carbon technology of the future) or (iii) general political apathy toward international obligations (i.e. the Canadian government has revised $CO_2$ emission reduction targets upward after claiming that the previous targets established by the former governing party were unrealistic). As nations adopt stronger public $CO_2$ emission reduction commitments, support for wind power tends to be elevated with the rising tide.
6. The presence of a *Vertically Integrated Utility Monopoly* is a political hurdle to wind power development for at least three reasons. First, monopolies exhibit bureaucratic, non-commercial ideologies that tend to resist change [99]. Second, government controlled monopolies are frequently insulated from external pressures to change. Strategic decisions regarding the types of fuel sources to be used for electricity generation are frequently made in well-insulated policy circles. This promotes "groupthink" wherein decisions made by the most powerful members of the strategic circle are embraced by all. The current situation in Taiwan exemplifies how this phenomenon can adversely impact wind power development. In Taiwan, key executives at Taipower (the government utility) do not believe there is sufficient wind power potential in the country to commit to aggressive wind power development programs. Third, utility monopolies are often mandated to keep electricity costs to a minimum; and as such, they can rarely accumulate sufficient capital to support wide-scale technology transitions [12].
7. *Weak Adjoining Grid Coordination* is a technical hurdle in that failure to effectively connect adjoining grids represents a missed opportunity to enhance grid stability and safely accommodate higher volumes of stochastic wind power. However, there is also a political dimension in that governments typically initiate the negotiations necessary to make such connections happen. One of the main reasons why Denmark has been capable of supporting such a high level of installed wind power capacity stems from its interconnectedness with the broader European grid [100,101]. In Australia, Canada and Japan, sub-optimal interconnectivity between regional grids prevents higher levels of wind power from being integrated into the respective grids without destabilizing operations.
8. *Lack of R&D Support for Wind Power* was shown to inhibit wind power development in all four case study nations. In all case study nations, wind power is apparently considered to be a mature, commercially viable alternative energy technology; and as such, the government has ceded support for wind power to the free market. Unfortunately, with many fossil fuel technologies also receiving government support, wind power developers are forced to compete on an uneven playing field. While it is perhaps understandable to leave R&D funding to major wind turbine manufacturers such as the Vestas and Goldstar in order to improve turbine efficiency, investment in storage technologies which are vital for utility-scale viability of both wind and solar power technologies need government intervention to consolidate focus.

## 4. Further research requirements and conclusion

The STEP framework presented in Section 3 conflates insights from four case study analyses to demonstrate that wind power development initiatives in any given nation are subject to impediments arising from social, technological, economic and political forces. The main implication of this for policymakers is that economic policy instruments designed to catalyze free-market change such as carbon taxation, emission trading schemes, renewable energy production subsidies or renewable energy production tax credits are subject to confounding forces from other STEP realms. Forebodingly, neglecting the influence of these forces puts any given economic policy at risk of producing sub-optimal results. Promisingly, attempts to mitigate these impediments might represent a way to achieve better policy results with less financial commitment.

Unfortunately, the STEP framework presented in this paper falls short of providing policymakers with a definitive cognitive framework of forces which inhibit wind power development for at least four reasons. First, the framework has been developed from data extracted from four case study nations. Analyses of more nations would help to validate the comprehensiveness of the variables presented in the STEP framework. Second, the four case study nations are all relatively advanced economies. It is likely that the forces identified in the framework may differ depending on whether a country is industrialized, developing or underdeveloped. For example, many underdeveloped countries are characterized as exhibiting poor infrastructure, high levels of corruption and autocratic governments. It is very likely that in such countries, conditions pertaining to these three variables alone would have a significant impact on the pace, scale and scope of wind power development. Two separate frameworks may be necessary for understanding wind power development hurdles in underdeveloped and developed countries. Third, although the framework identified key STEP variables which have influence over wind power development in advanced nations, word limitations precluded an evaluation of the *relative* influence that these variables have on change within a given electricity regime. Understanding the relative influence of each variable is a necessary exercise if policymakers are to identify forces which will have the strongest potential for catalyzing electricity regime change. Fourth, given the numerous inter-relationships between the STEP forces, attempts must also be made to understand the nature of these connections and explicate how the forces which inhibit wind power development respond to changes occurring to other factors within the complex adaptive policy system. All four of these limitations need to be subjugated through further research in order to move the STEP framework forward from being a conceptual tool to a practical tool that policymakers can use to guide the development of better wind power development policy.

In closing, it is worth reiterating that this analysis began with a question. Are there other obstacles that extend beyond the realm of economic rationality that inhibit the development of wind power, and if so what are they? The STEP framework presented in this paper presents evidence that non-economic obstacles do exist and provides a clearer explication of both economic and non-economic barriers to wind power development. Although the STEP categories might require refinement as more nations are examined in the context of this framework and deeper understanding of the influence that each STEP force has on wind power development both directly and indirectly (through catalyzing change in other forces) is required to allow policymakers to fully utilize the STEP analysis for improving wind power development policy, the framework as presented indisputably achieves the goals of demonstrating that other non-economic barriers to wind power exist and cataloguing the forces in manageable STEP clusters. From

this perspective alone, the analysis presented herein advances understanding of the socio-technical political economy of wind power development. If policymakers took steps to try and mitigate the confounding influences of the barriers identified in this STEP framework, it is likely that the efficacy of wind power development policy would be improved, if only by one STEP.


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